FTD-MT-24-1583-71

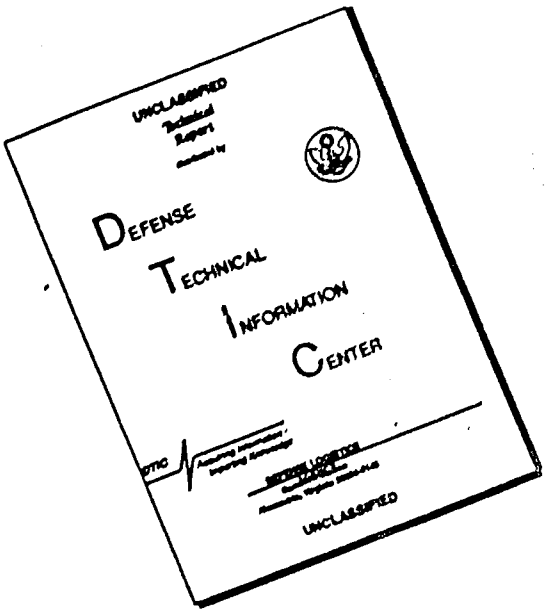
FOREIGN TECHNOLOGY DIVISION

THE VISCOSITY OF METHANE-NITROGEN AND METHANE-NITROGEN-HYDROGEN MIXTURES AT TEMPERATURES FROM 273 TO 473°K AND PRESSURES TO $490.3 \cdot 10^5$ N/m^2

by

N. Ye. Gnezdilov and I. F. Golubev

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

FTD-MT- 24-1583-71

EDITED MACHINE TRANSLATION

THE VISCOSITY OF METHANE-NITROGEN AND METHANE-NITROGEN-HYDROGEN MIXTURES AT TEMPERATURES FROM 273 TO 473°K AND PRESSURES TO 490.3·10^5 N/m^2

By: N. Ye. Gnezdilov and I. F. Golubev

English pages: 6

Source: Gazovaya Promyshlennost' (The Gas Industry), Vol. 13, No. 4, 1968, pp. 46-48.

This document is a SYSTRAN machine aided translation, post-edited for technical accuracy by: Charles T. Ostertag.

IR/0492-68-013-004

PREPARED BY:

TRANSLATION DIVISION
FOREIGN TECHNOLOGY DIVISION
WP-AFB, OHIO.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)
Foreign Technology Division
Air Force Systems Command
U. S. Air Force

2a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

2b. GROUP

3. REPORT TITLE
THE VISCOSITY OF METHANE-NITROGEN AND METHANE-NITROGEN-HYDROGEN MIXTURES AT TEMPERATURES FROM 273 TO 473 DEGREES K AND PRESSURES TO 490.3 TIMES 10^5 N/m^2

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Translation

5. AUTHOR(S) (First name, middle initial, last name)
Gnezdilov, N. Ye., and Golubev, I. F.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
1968	6	3

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. F-3615-71-C-1182 (71 Jan 01)	FTD-MT-24-1583-71
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT
Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Foreign Technology Division Wright-Patterson AFB, Ohio

13. ABSTRACT

Mixtures containing methane, nitrogen, and hydrogen are frequently encountered in the industrial practice of the gas and economical industry, for example in the processes of conversion of methane, synthesis of ammonia, and others. For the hydrodynamic and thermal calculations of these processes it is required to know the viscosity coefficients of mixtures containing the indicated components at various temperatures and pressures. At the present time data are available on the viscosity of mixtures containing methane, nitrogen, and hydrogen which were obtained earlier for one binary mixture with given composition, percentages, temperatures and pressures.

DD FORM 1 NOV 65 1473

UNCLASSIFIED

Security Classification

UNCLASSIFIED

Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Viscosity High Pressure Methane Nitrogen Hydrogen						

UNCLASSIFIED

Security Classification

U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

* ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

THE VISCOSITY OF METHANE-NITROGEN AND METHANE-NITROGEN-HYDROGEN MIXTURES AT TEMPERATURES FROM 273 TO 473°K AND PRESSURES TO $490.3 \cdot 10^5$ N/m^2

N. Ye. Gnezdilov and I. F. Golubev

Mixtures containing methane, nitrogen, and hydrogen are frequently encountered in the industrial practice of the gas and chemical industry, for example in the processes of conversion of methane, synthesis of ammonia, and others.

For the hydrodynamic and thermal calculations of these processes it is required to know the viscosity coefficients of mixtures containing the indicated components at various temperatures and pressures. At the present time data are available on the viscosity of mixtures containing methane, nitrogen, and hydrogen which were obtained earlier [1] for one binary mixture with the composition 80% CH_4 + 20% N_2 at temperatures of 293, 323.6, and 373.2°K and pressures from 0.1013 to 30.39 mN/m^2 and for three ternary mixtures with the composition 37.85% CH_4 + 16.80% H_2 + 45.34% N_2 at temperatures from 294.4 to 373.5°K and pressures from 0.1013 to 30.39 mN/m^2; the composition 19.8% CH_4 + 24.7% H_2 + 55.5% N_2 at temperatures from 285.7 to 373.9°K and pressures from 0.1013 to 30.39 mN/m^2; and the composition 17% CH_4 + 62.5% H_2 + 20.5% N_2 at temperatures from 298 to 473°K and pressures from 0.1013 to 81.04 mN/m^2.

Using the capillary method on the previously described installation [1] we continued and expanded the measurements of the viscosity of mixtures containing these components. We determined the viscosity of

two binary mixtures with the composition 27.8% CH_4 + 72.2% N_2 and 55.1% CH_4 + 44.9% N_2 at temperatures from 273 to 473°K and pressures to 49.03 mN/m^2 and two ternary mixtures with the composition 21.8% CH_4 + 57.7% H_2 + 20.5% N_2 and 18.9% CH_4 + 49.8% H_2 + 31.4% N_2 at temperatures from 273 to 473°K and pressures to 49.03 mN/m^2. The results of the measurements are given in Tables 1-4.

Table 1. Viscosity (10^{-3} N·s·m^{-2}) for the mixture: 27.8% CH_4 + + 72.2% N_2.

p, N/m^2·10^5 по манометру	(2) Температура, °K					
	273,15	298,15	323,15	373,15	423,15	473,15
0	1474	1575	1671	1854	2034	2209
9.807	1489	1590	—	1868	—	—
19.60	1504	1607	1699	1878	2054	2213
19.60	1510	—	—	—	—	—
49.03	1567	1654	1742	1911	2066	2229
49.03	1573	—	—	1925	—	—
98.07	1708	1779	1848	2000	2149	2292
148.0	1893	1934	2000	2092	2221	2362
148.0	1902	—	2018	—	2230	—
196.0	2107	2104	2168	2211	2310	2426
196.0	2121	—	—	—	—	2436
245.2	2318	2280	2312	2324	2405	2512
245.2	2360	—	—	—	—	—
294.2	2552	2469	2450	2442	2508	2604
294.2	—	2498	—	—	—	—
343.2	2783	2669	2603	2562	2606	2682
343.2	2766	—	—	—	—	—
392.3	3000	2851	2741	2693	2716	2774
392.3	3008	—	2769	—	—	—
441.3	3195	3007	2920	2816	2818	2833
441.3	—	3038	—	—	—	—
490.3	3356	3180	3061	2955	2930	2941
490.3	3368	3207	3081	—	2970	—

KEY: (1) p, N/m^2·10^5 on a manometer; (2) Temperature, °K.

Table 2. Viscosity (10^{-3} N·s·m^{-2}) for the mixture: 55.1% CH_4 + + 44.9% N_2.

p, N/m^2·10^5 по манометру	(2) Температура, °K					
	273,15	298,15	323,15	373,15	423,15	473,15
0	1311	1405	1493	1663	1831	1989
9.807	—	1419	1509	1670	—	—
19.60	1314	1436	—	1687	1850	2007
49.03	1417	1493	1567	1723	1882	2039
49.03	1394	—	—	—	—	—
98.07	1561	1600	1665	1801	1945	2086
98.07	—	1621	1680	—	—	—
148.0	1784	1778	1808	1901	2028	2149
196.0	2042	1994	1968	2021	2111	2224
196.0	2051	—	—	—	—	—
245.2	2268	2190	2136	2155	2216	2312
245.2	2282	—	2149	—	—	—
294.2	2552	2387	2319	2291	2340	2396
343.2	2769	2595	2492	2415	2444	2486
343.2	2750	—	—	2426	—	—
392.3	2953	2786	2660	2562	2546	2579
441.3	3167	2956	2819	2685	2619	2663
441.3	3173	2971	2830	2700	—	—
490.3	3327	3146	2992	2814	2751	2765
490.3	3332	3150	2974	2821	2764	—

KEY: (1) p, N/m^2·10^5 on a manometer; (2) Temperature °K.

The data obtained on the methane-nitrogen binary mixtures were processed in coordinates "excess viscosity ($\eta_{pT}-\eta_0$) – density ρ" (Fig. 1, curves II and III). The same processing was conducted for the data of work [1] (curve I).

The experimental points for all temperatures are arranged well on one general curve for every mixture. The values of density for the given methane-nitrogen mixtures were taken from work [2].

Table 3. Viscosity (10^{-8} N·s·m^{-2}) for a mixture: 21.8% CH_4 + 57.7% H_2 + 20.5% N_2.

(1) p, N/м²·10⁵ по манометру	(2) Температура, °К						
	273,15	298,15	323,15	373,15	423,15	473,15	523,15
0	1256	1340	1421	1575	1724	1874	2022
9.807	1261	1344	1439	1579	1726	—	2026
9.807	1264	—	1425	—	—	—	—
19.60	1264	1347	—	—	—	—	2027
19.60	—	1354	—	—	—	—	—
49.03	1300	1381	1463	1602	1744	1881	2035
49.03	1296	—	—	—	—	—	—
98.07	1360	1442	1511	1633	1772	1916	2061
98.07	1369	—	—	1631	—	—	—
148.0	1441	—	1570	1689	1811	1945	2092
148.0	1453	1508	1561	1681	—	—	—
196.0	1533	1580	1624	1743	1856	1984	2124
196.0	1541	1592	—	—	1848	—	—
245.2	1627	1666	1701	1803	1905	2021	2154
245.2	—	1670	1708	1794	—	—	—
294.2	1722	1748	1774	1855	1949	2063	2186
294.2	—	1754	—	—	1941	—	—
343.2	1818	1830	1847	1904	1995	2094	2217
343.2	1823	—	—	1915	—	—	—
392.3	1916	1911	1919	1966	2032	2139	2248
392.3	—	—	—	1957	—	—	—
441.3	2011	1991	1990	2021	2084	2175	2281
441.3	—	—	—	—	2091	—	—
490.3	2116	2071	2061	2073	2132	2212	2311
490.3	2106	2080	—	—	—	—	—

KEY: (1) p, N/m^2·10^5 on a manometer. (2) Temperature, °K.

Table 4. Viscosity (10^{-8} N·s·m^{-2}) for a mixture: 18.8% CH_4 + 49.8% H_2 + 31.4% N_2.

(1) p, Н/м²·10⁵ по манометру	(2) Температура, °К					
	273,15	298,15	323,15	373,15	423,15	473,15
0	1408	1501	1588	1756	1913	2065
9.807	1412	—	1593	1760	—	2069
9.807	—	—	1596	1764	—	—
19.60	1428	1514	1605	1769	1922	—
19.60	—	—	1600	1764	—	—
49.03	1466	1551	1633	1794	1943	2089
49.03	1460	1548	—	—	—	—
98.07	1549	1620	1692	1841	1984	2116
98.07	—	1625	—	1834	—	—
148.0	1652	1702	1760	1893	2024	2150
148.0	—	1713	—	1888	2033	—
196.0	1761	1800	1835	1953	2075	2191
196.0	1764	—	1843	—	—	—
245.2	1872	1890	1920	2014	2132	2225
245.2	—	—	1925	—	2124	—
294.2	1985	1985	2008	2084	2186	2263
294.2	—	1986	—	—	2191	—
343.2	2094	2077	—	2150	2233	2299
343.2	-	2073	2085	—	—	—
392.2	2193	2173	—	2213	2285	2334
392.2	-	2175	2165	—	—	—
441.3	2301	2266	2246	2276	2334	2374
441.3	—	—	2250	—	2340	—
490.3	2402	2363	2330	2340	2392	2411
490.3	2409	2356	2336	—	—	—

KEY: (1) p, N/m^2·10^5 on a manometer. (2) Temperature, °K.

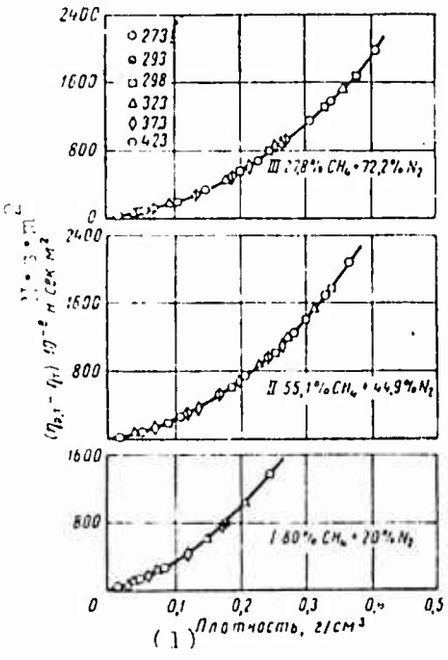


Fig. 1. Dependence of ($\eta_{p,T}-\eta_T$) on density for a CH_4–N_2 mixture.
KEY: (1) Density, g/cm^3.

As an example Figure 2 shows the dependence of the viscosity of the methane-nitrogen mixture on composition at a temperature of 323°K and various pressures. It should be noted that the graphic processing of the experimental data on the dependence of the viscosity of methane-nitrogen mixtures on composition and other temperatures showed a picture analogous to that depicted in Fig. 2. Here the data of work [1] are arranged well on the curves of dependence on composition at all the investigated temperatures (an exception are the data obtained at atmospheric pressure).

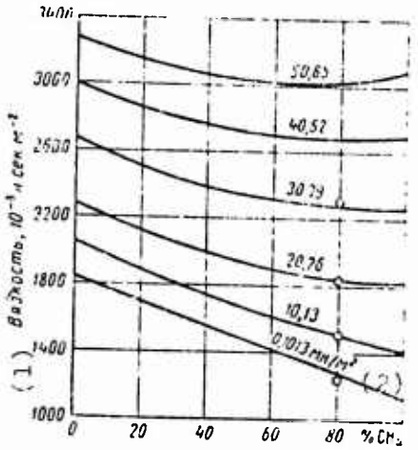


Fig. 2. The viscosity of a CH_4-N_2 mixture at 323°K and various pressures ——— – according to the authors, O – according to work [1].
KEY: (1) Viscosity, 10^{-6} N·s·m^2; (2) mN/M^2

Figure 3 depicts the results of experimental measurements for one of the ternary mixtures of methane-hydrogen-nitrogen. Such a picture is also observed for the second investigated mixture.

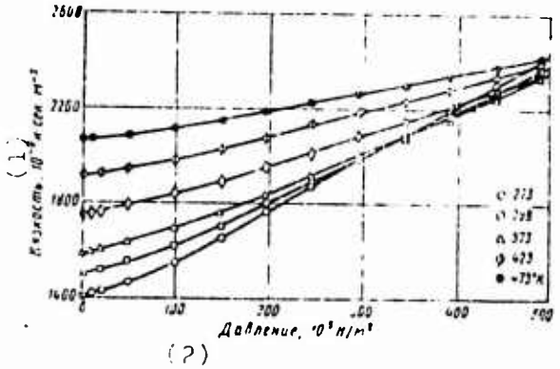


Fig. 3. The viscosity of the mixture 18.8% CH_4 + 49.8% H_2 + 31.4% N_2 depending on pressure and temperature
KEY: (1) Viscosity, 10^{-8} N·s·m^2; (2) Pressure, 10^5 N/m^2.

Figure 4 depicts the processing of the laboratory findings on the viscosity of ternary mixtures in the coordinates "excess viscosity-density", showing also that for triple (multicomponent) mixtures there is a uniform dependence of excess viscosity on density at various temperatures.

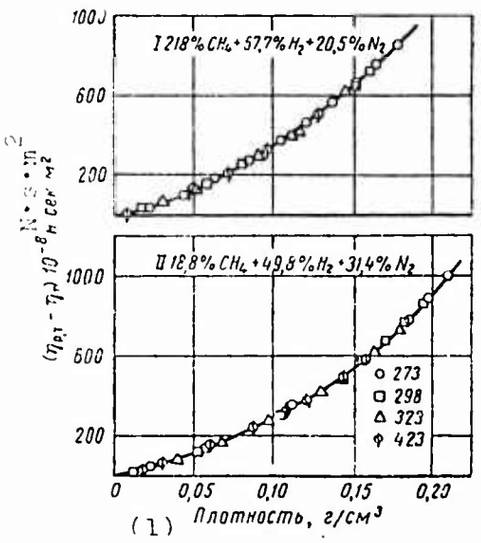


Fig. 4. Dependence of $(\eta_{p,T}-\eta_0)$ on density for a CH_4–H_2–N_2 mixture. KEY: (1) Density, g/cm^3.

The values of density for ternary mixtures used in this processing were calculated according to the Krichevskiy-Kazarnovskiy equation [3] with the constants given in work [2].

CONCLUSIONS

The laboratory findings, measured by the capillary method, are given for mixtures with the composition: 27.8% CH_4 + 72.2% N_2; 55.1% CH_4 + 44.9% N_2; 21.8% CH_4 + 57.7% H_2 + 20.5% N_2; and 18.8% CH_4 + 49.8% H_2 + 31.4% N_2 at temperatures from 273 to 473°K and pressures to 49.03 MN/m^2.

The processing of the experimental results showed the unique dependence of excess viscosity on density at all temperatures.

BIBLIOGRAPHY

[1] Голубев И. Ф. Вязкость газов и газовых смесей. Физматгиз, 1959.
[2] Кричевский И. Р., Левченко Г. Т. Ж. Физ. Хим., т. 15 1941.
[3] Кричевский И. Р., Казарновский Л. С. Ж. Физ. Хим., т. 13, 1939.

(GIAP)

(GIAP [State Scientific Research and Planning Institute of the Nitrogen Industry and Products of Organic Synthesis])